IMMERSIVE VIRTUAL REALITY SCENES USING RADIANCE
COMPARISON OF REAL AND VIRTUAL ENVIRONMENTS

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RADIANCE INTERNATIONAL WORKSHOP
2016

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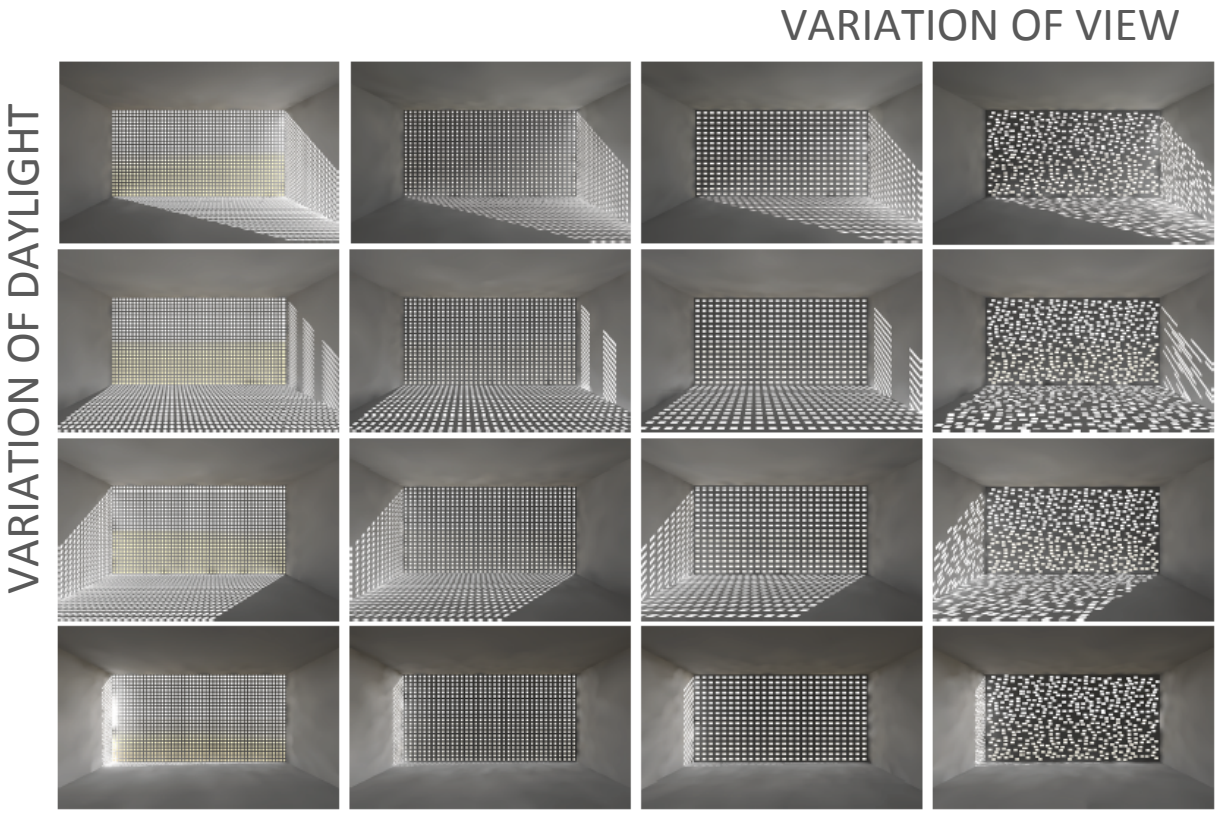
thesis director
Dr.-Ing. Jan Wienold
thesis co-director

TRODUCTION

OTIVATION: KYNTHIA'S DOCTORAL RESEARCH

subjective experiments



Which **pattern factors** (if any) lead to changes in the **perceived spatial ambienc**

OTIVATION: KYNTHIA'S DOCTORAL RESEARCH

challenges in real space experiments

- change of façade pattern
- variation of luminous conditions

2D rendering?

- limited luminance range
- lacking immersion

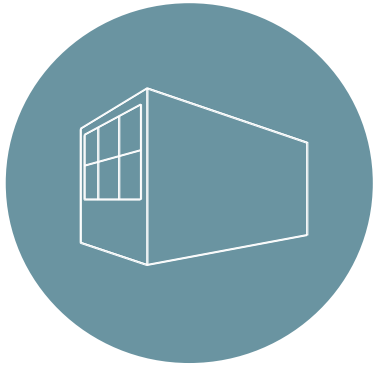
problematic for evaluation of
- pleasantness[1]
- distribution of light[1]

013[1]]

OTIVATION: KYNTHIA'S DOCTORAL RESEARCH

Oculus Rift
Virtual Reality Headset

OTIVATION: KYNTHIA'S DOCTORAL RESEARCH



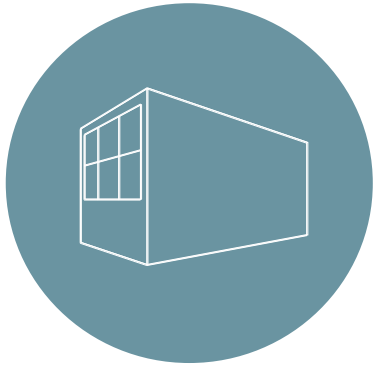
feasibility
study

virtual space
experiments

statistical model

real space
experiments

OTIVATION: KYNTHIA'S DOCTORAL RESEARCH



feasibility study

virtual space experiments

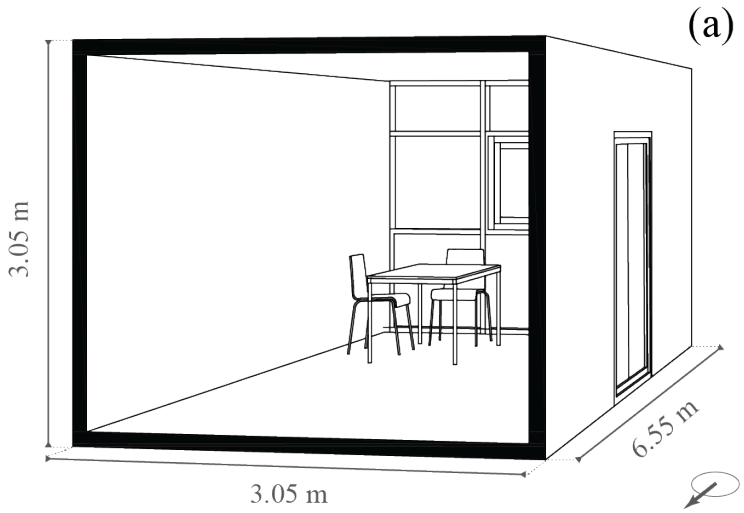
statistical model

real space experiments

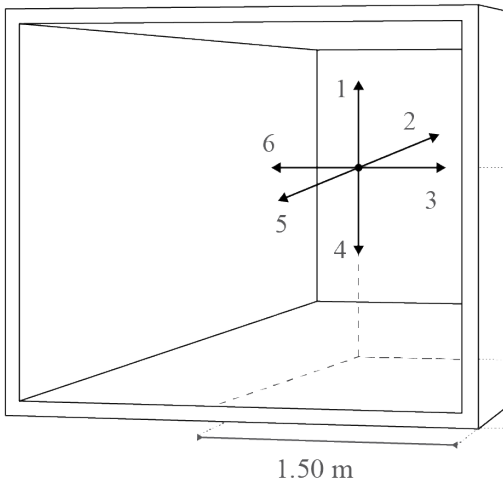
ASIBILITY STUDY: GENERATION OF VIRTUAL SCENES

Immersive virtual representation
of the DEMONA **test room**

DEMONA test room,
EPFL



3D model of the test room



viewpoint set
in the center of the roo

ASIBILITY STUDY: GENERATION OF VIRTUAL SCENES

Immersive virtual representation
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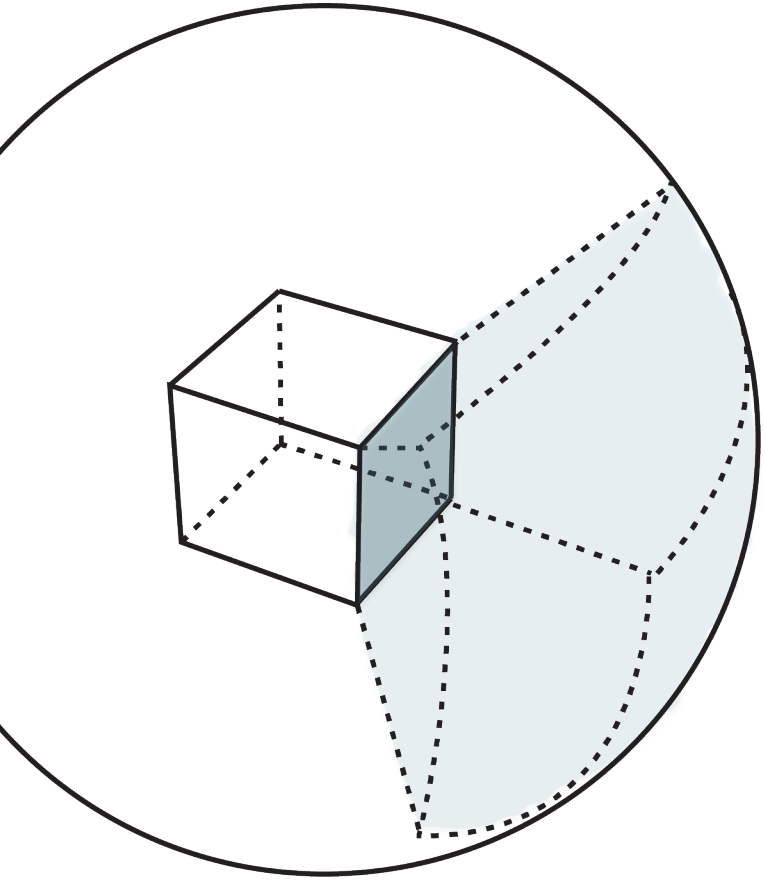
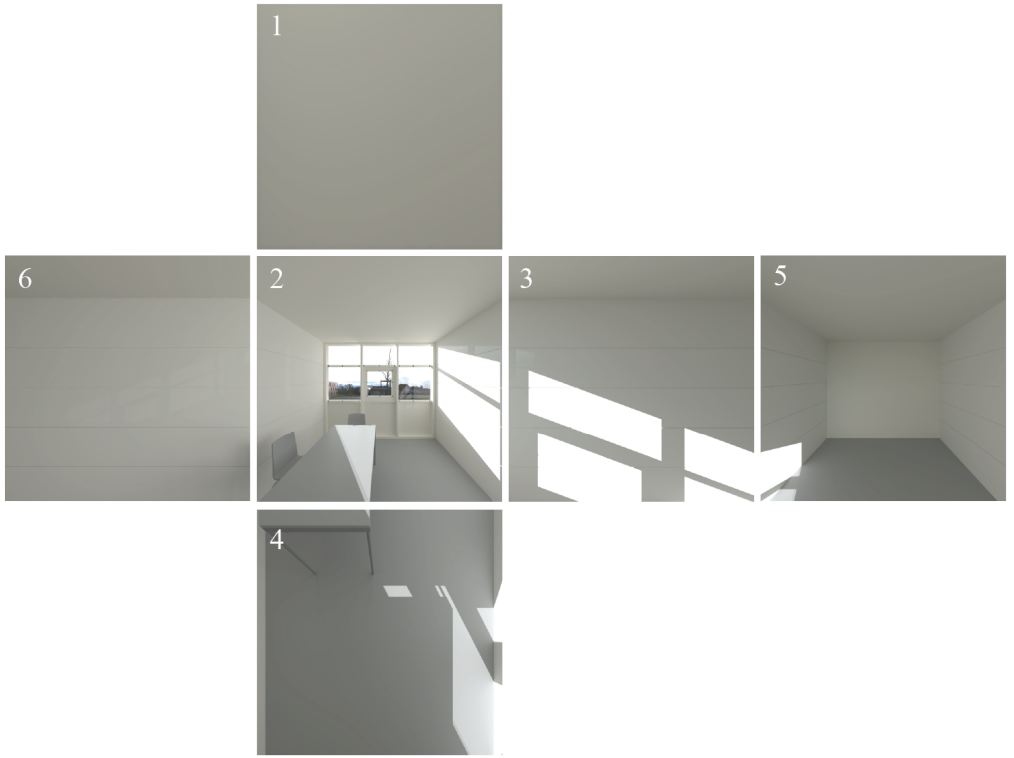
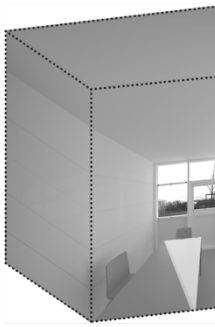
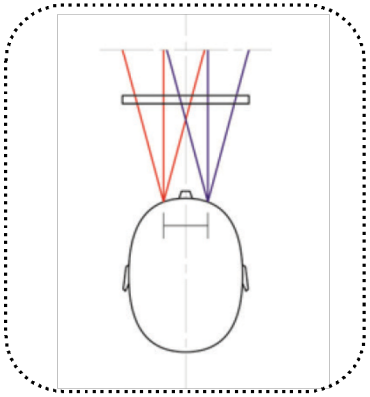






ASIBILITY STUDY: GENERATION OF VIRTUAL SCENES

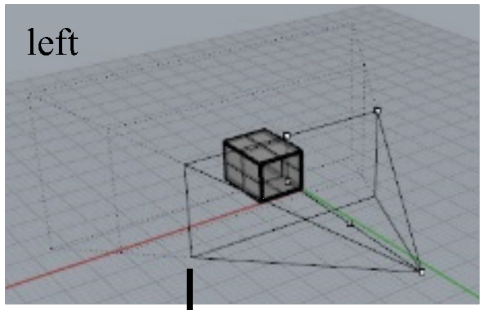


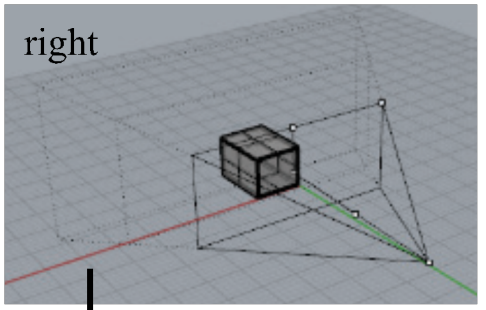
Rhinoceros 5

DIVA FOR RHINO
ENVIRONMENTAL ANALYSIS FOR BUILDINGS

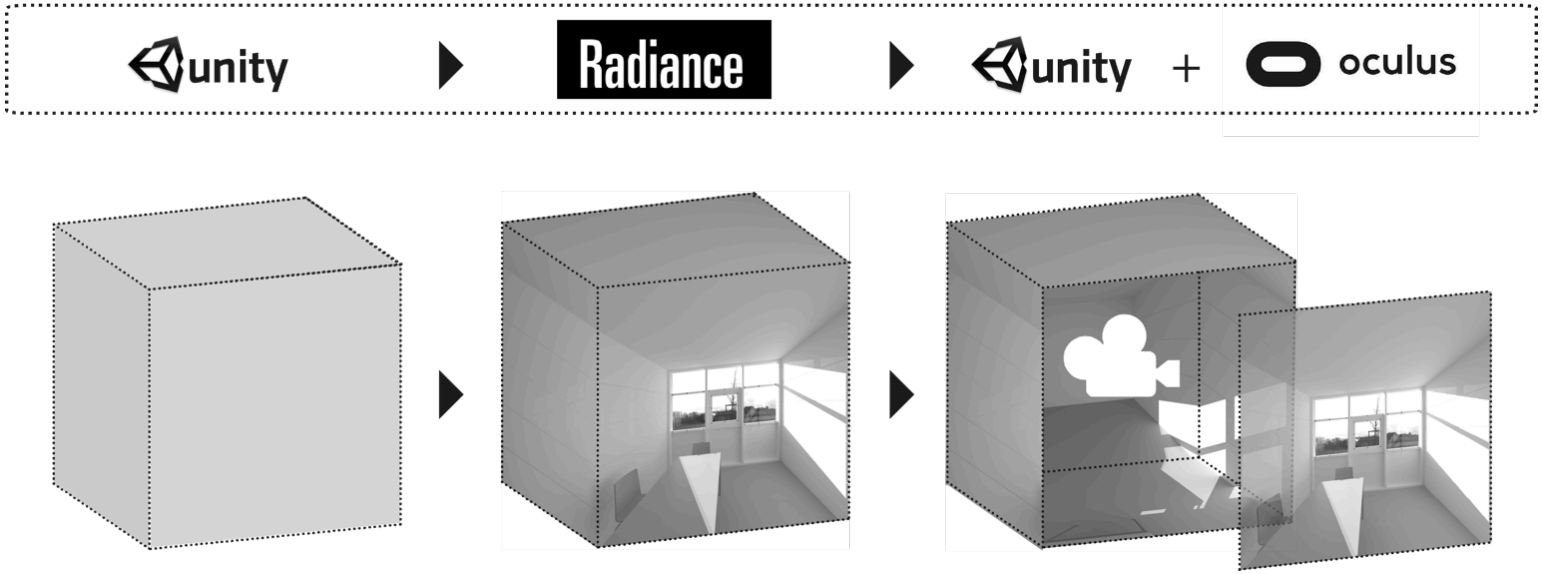
Radiance

Rendering pairs: one image for each eye





asibility STudy: GEneration Of Virtual Scenes



XPERIMENTAL RESULTS

asibility STudy: REal VErsus VIrtual SPace







9:30 10:30 11:30 12:30 13:30 14:30 15:30

10 immersive
virtual scenes

7 with **clear** sky

hourly time steps from 9:30-15:30

3 with **overcast** sky

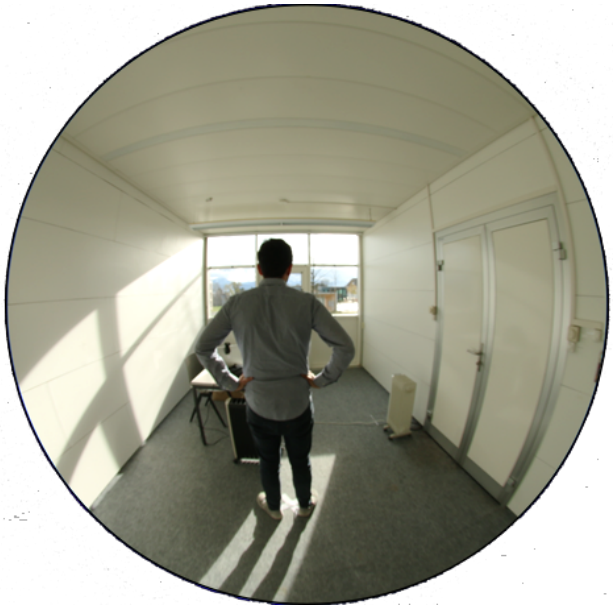
different view out conditions

*presented according to **similarity** with conditions **in real space***

***limited similarity** due to time constraints*

asibility STudy: REal VErsus VIrtual SPace

subject exploring
the **virtual** space

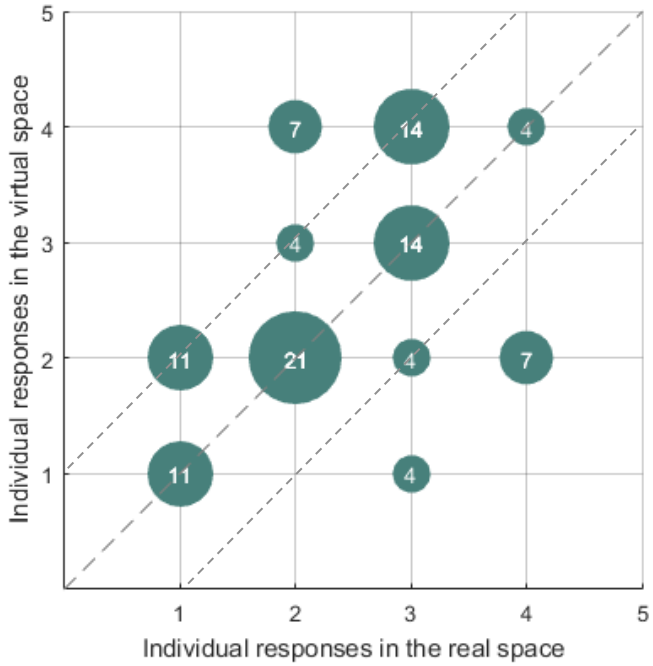


subject exploring
the **real** space

- *ambience* questionnaire for each space
- physical symptoms *before* and *after* the session
- perceived presence in the virtual environment

ESULTS: EVALUATION OF REAL VERSUS VIRTUAL SPACE

How **pleasant** do you find this space?

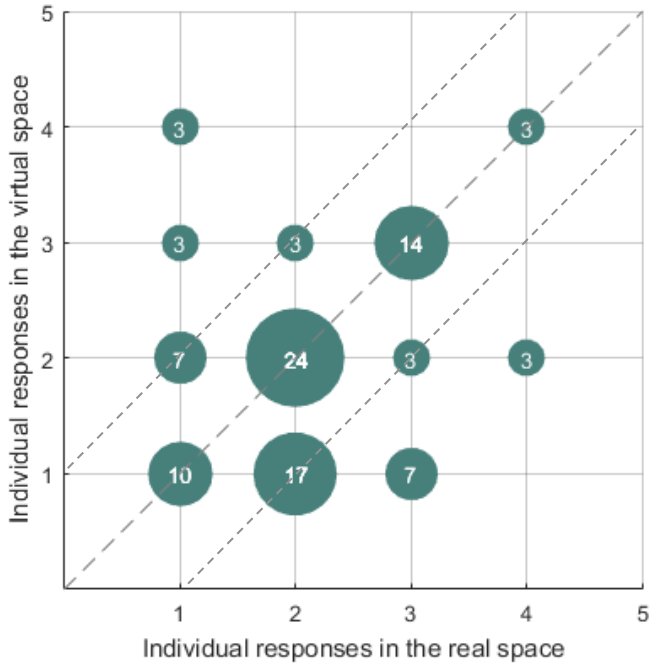


scatter plot mark text = frequency of responses (%)

	N subjects	Percentage of pairs with absolute difference (%) 0	1	0 and 1
pleasant	28	**50**	32	**82**
interesting	29	**52**	31	**83**
complex	29	**76**	24	**100**
exciting	28	43	47	**90**
satisfied with amount of view	29	**52**	45	**97**

ESULTS: EVALUATION OF REAL VERSUS VIRTUAL SPACE

How **interesting** do you find this space?



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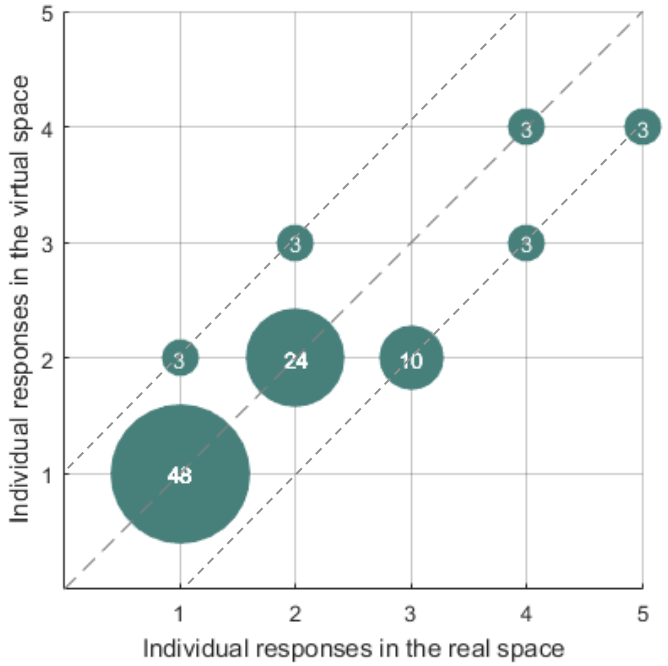
ESULTS: EVALUATION OF REAL VERSUS VIRTUAL SPACE

How **complex** do you find this space?



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	N subjects	*Percentage of pairs with absolute difference (%)* *0*	*1*	*0 and 1*
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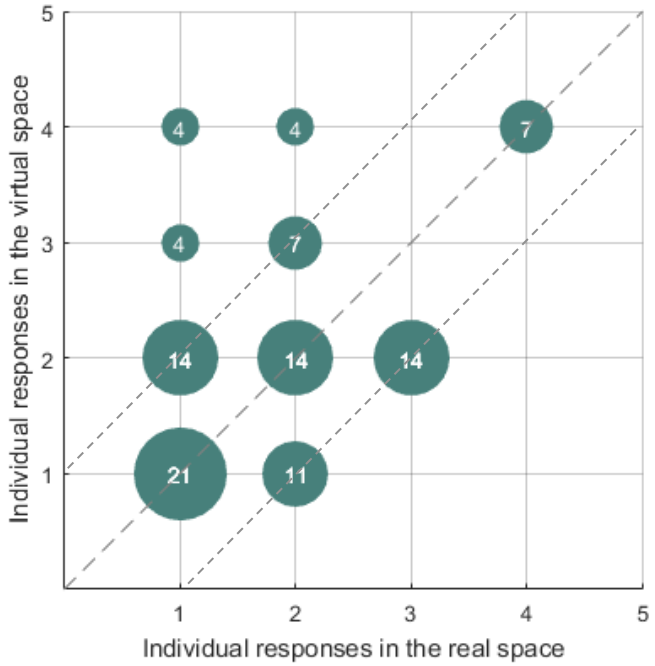
ESULTS: EVALUATION OF REAL VERSUS VIRTUAL SPACE

How **exciting** do you find this space?



scatter plot mark text = frequency of responses (%)

	N subjects	*Percentage of pairs with absolute difference (%)* *0*	*1*	*0 and 1*
pleasant	28	**50**	32	**82**
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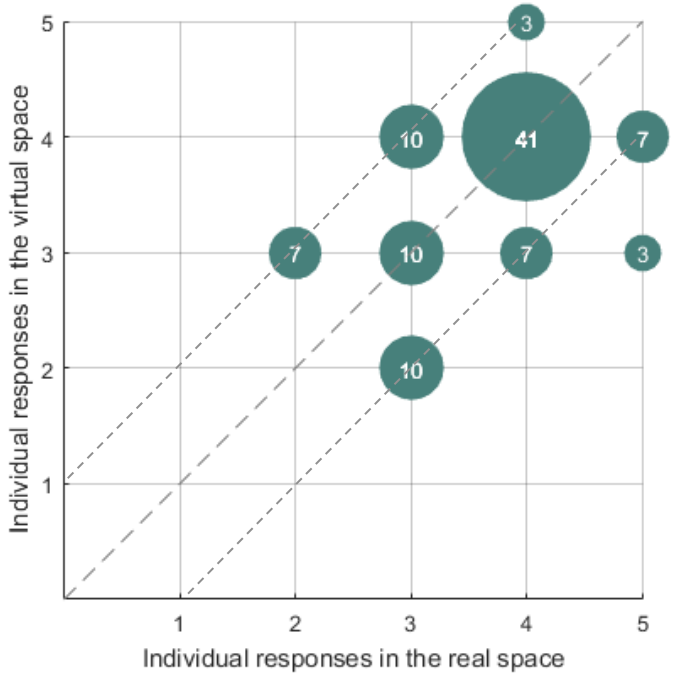
ESULTS: EVALUATION OF REAL VERSUS VIRTUAL SPACE

How **satisfied** are you with the **amount of view** in this space?



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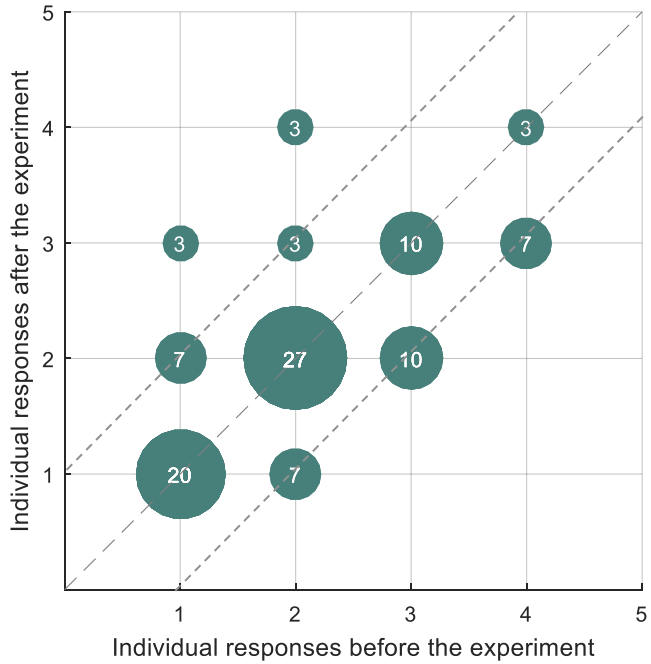
ESULTS: EVALUATION OF REAL VERSUS VIRTUAL SPACE

marked attributes:
adequate perceptual accuracy in the virtual space

	N subjects	*Percentage of pairs with absolute difference (%)*				
		0	*1*	*2*	*3*	*0 and 1*
pleasant	28	**50**	32	18	0	**82**
interesting	29	**52**	31	14	3	**83**
complex	29	**76**	24	0	0	**100**
exciting	28	43	47	7	3	**90**
satisfied with amount of view	29	**52**	45	3	0	**97**

ESULTS: PHYSICAL SYMPTOMS BEFORE AND AFTER THE USE OF VR

How **fatigued** do you feel?



scatter plot mark text = frequency of responses (%)

	N subjects	Percentage of pairs with absolute difference (%) 0	1	0 and 1
fatigue	30	**60**	34	**94**
clear vision	30	**80**	16	**96**
fresh head	30	44	43	**87**
sore eyes	30	**66**	22	**88**

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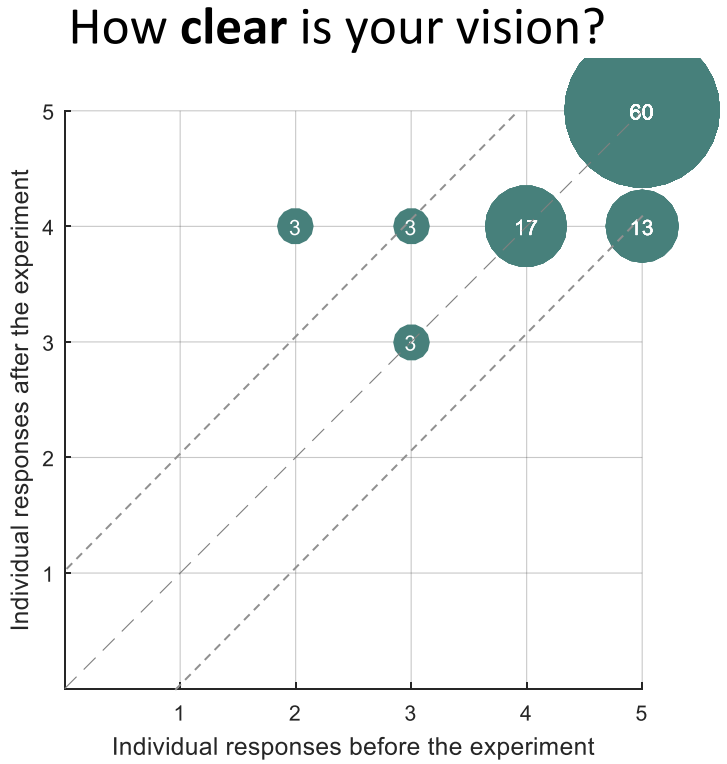

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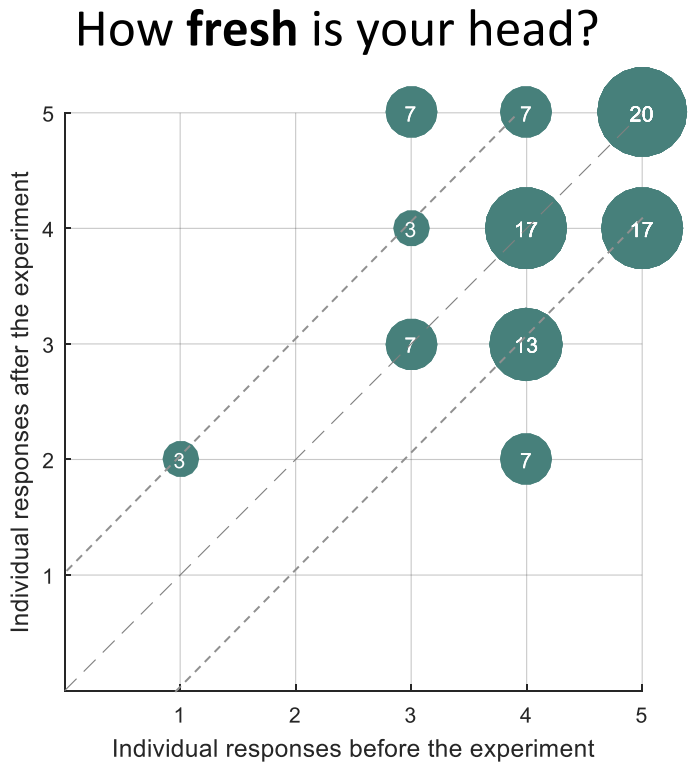

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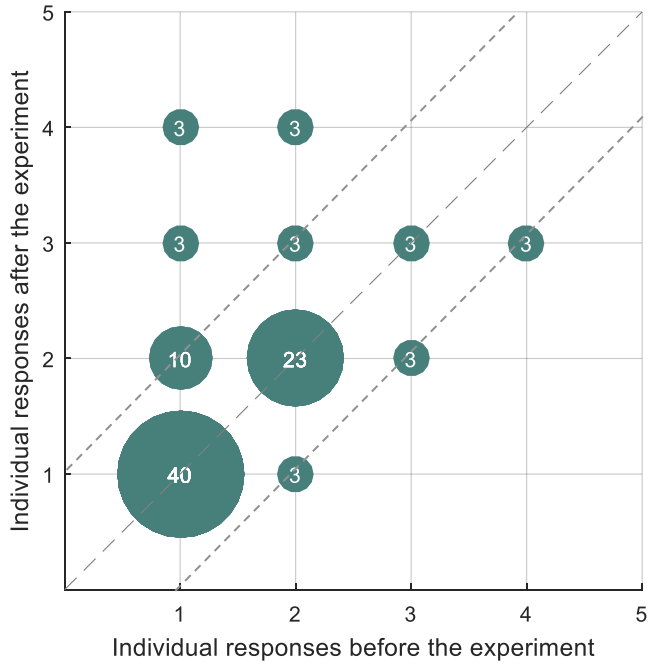
ESULTS: PHYSICAL SYMPTOMS BEFORE AND AFTER THE USE OF VR

How **sore** are your eyes?



scatter plot mark text = frequency of responses (%)

	N subjects	*Percentage of pairs with absolute difference (%)* *0*	*1*	*0 and 1*
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fresh head	30	44	43	**87**
sore eyes	30	**66**	22	**88**

ESULTS: EVALUATION OF REAL VERSUS VIRTUAL SPACE


marked attributes:
negligible physical symptoms after the use of the VR headset

	N subjects	*Percentage of pairs with absolute difference (%)*		
		0	*1*	*0 and 1*
fatigue	30	**60**	34	**94**
clear vision	30	**80**	16	**96**
fresh head	30	44	43	**87**
sore eyes	30	**66**	22	**88**

ire based on Shibata et al., 2011.

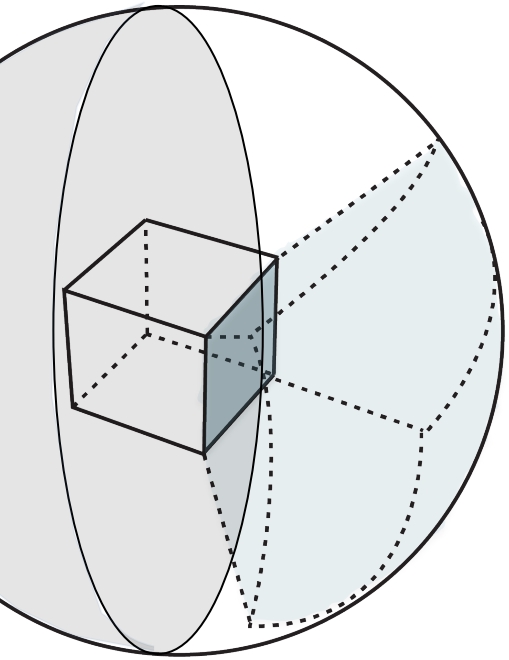
ESULTS: PRECEIVED PRESENCE IN THE VIRTUAL SPACE

1] How much did you feel like "**being there**" in the **virtual space**?

aire based on Witmer and Singer, 1994.

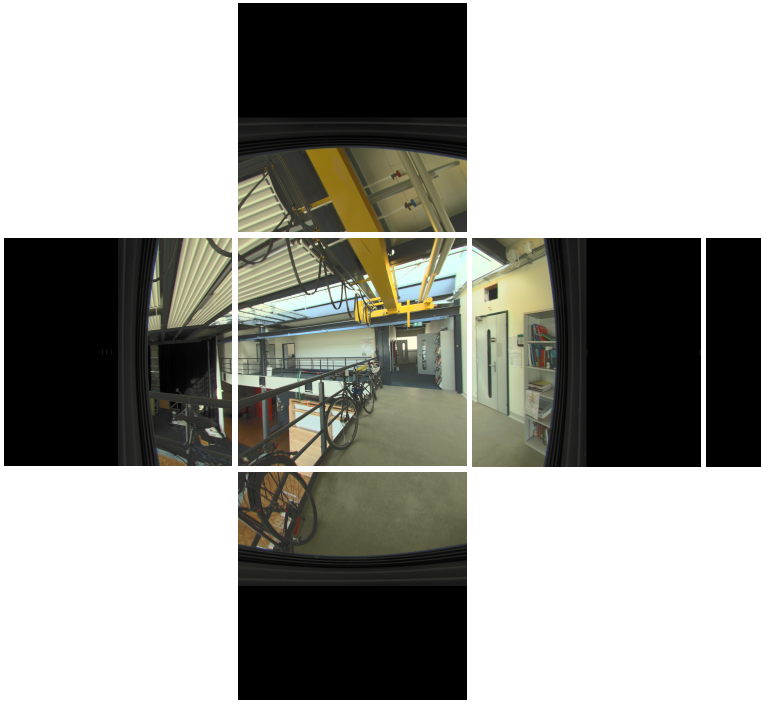
NGOING & FUTURE WORK

Immersive **hemispherical scene** from **HDR photograph**



immersive
hemisphere

180° fisheye image
with a SIGMA 4.5mm F2.8 lens



cube mapping using *pinterp*
(monoscopic projection)

NGOING AND FUTURE WORK

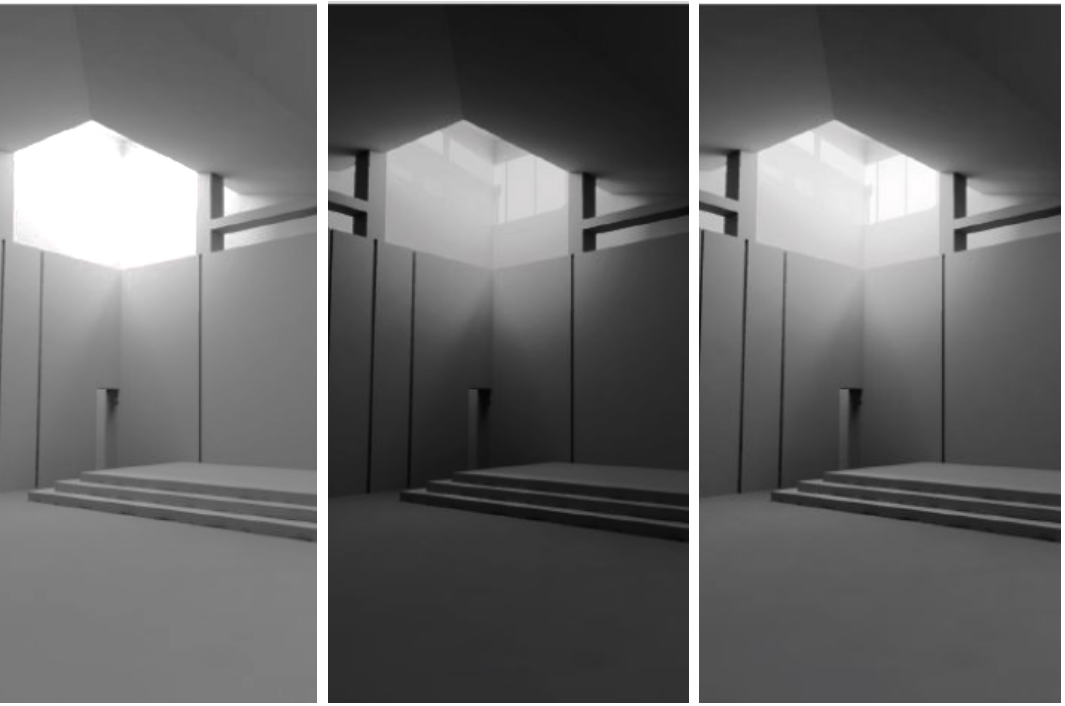
180° fisheye HDR
h a SIGMA 4.5mm F2.8 lens

adequacy of tonemapping algorithms
in immersive virtual environments

perceptual accuracy of device (Oculus Rift CV1)
in photographic immersive scenes

NGOING AND FUTURE WORK

improvement of **perceptual accuracy** of the **virtual scene**



tone-mapping algorithm,
new VR headset,
scene details & view out

VR **immersion** in **architectural spaces**

upcoming experiment
with Siobhan Rockcastle

Thank you! ☺

✉ kynthia.chamilothori@epfl.ch

Perceptual accuracy with different **tonemapping algorithms**

180° fisheye HDR
a SIGMA 4.5mm F2.8 lens

Pcond[1]

Reinhard02[2]

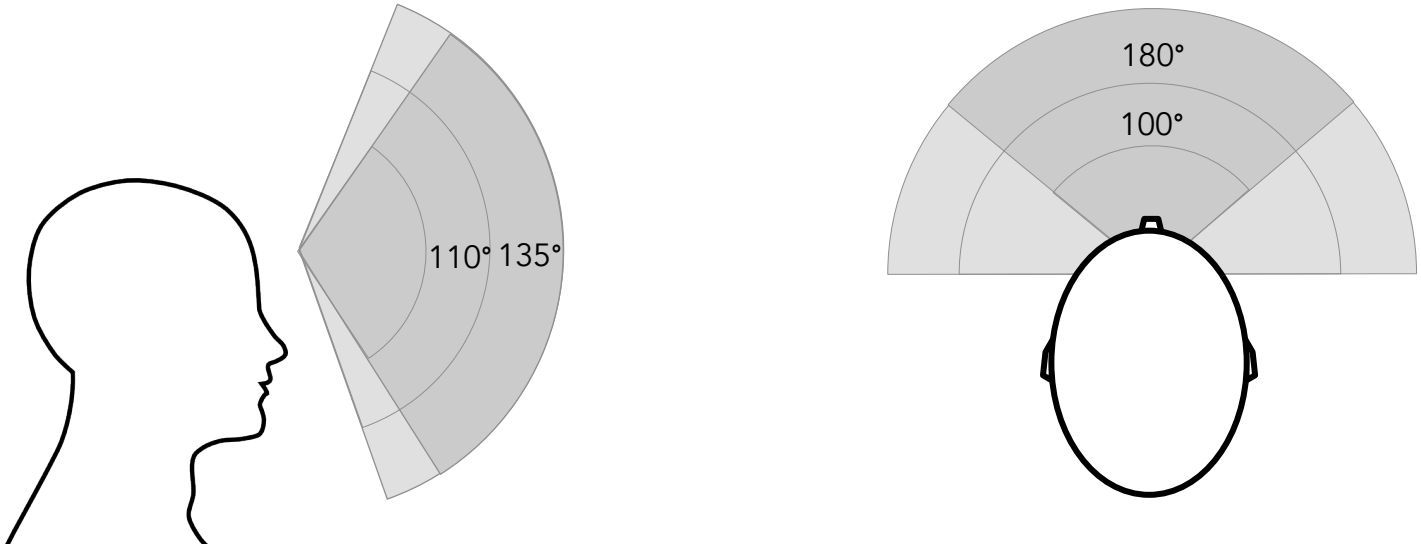
Durand&Dorsey02[3]

[1] Ward, 1994 [2] Reinhard, 2003 [3] Durand and

OCULUS RIFT

Oculus Rift Specifications

Vertical and **horizontal visual field**
in normal vision and through Oculus Rift



Oculus Rift visual field range

Human visual field range

Oculus Rift Specifications

	Developer's Kit 2	Consumer Version
Resolution:	960 x 1080 per eye	1080 x 1200 per eye
Refresh rate:	75 Hz	90 Hz
Field of View:	100°	110°

APPLICATION

asibility STudy: FAÇAde PAtterns

subject exploring
the **virtual** space

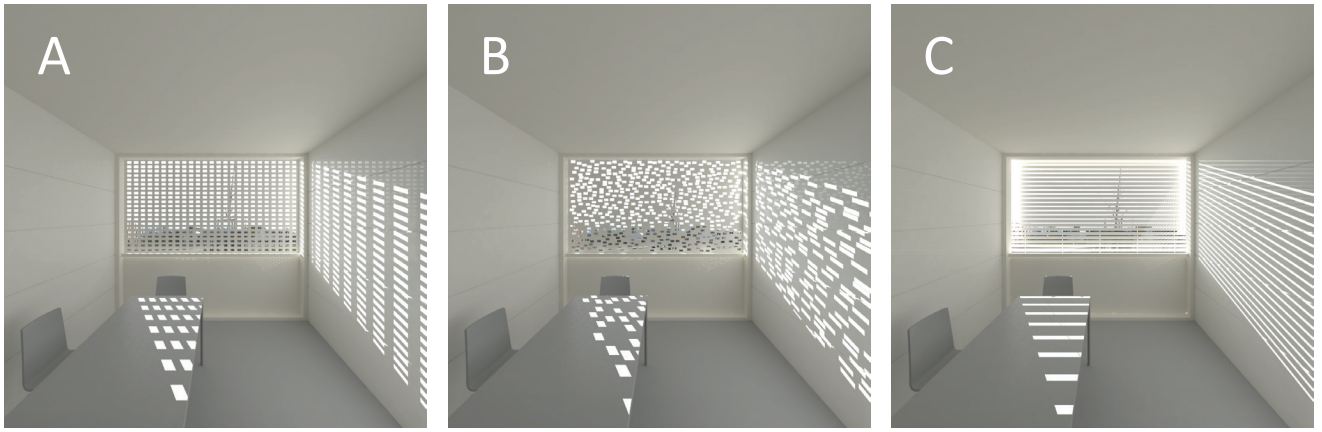
subject exploring
the **real** space

ambience questionnaire for each space

three pattern configurations under the same sky

asibility STudy: FAÇAde PAtterns

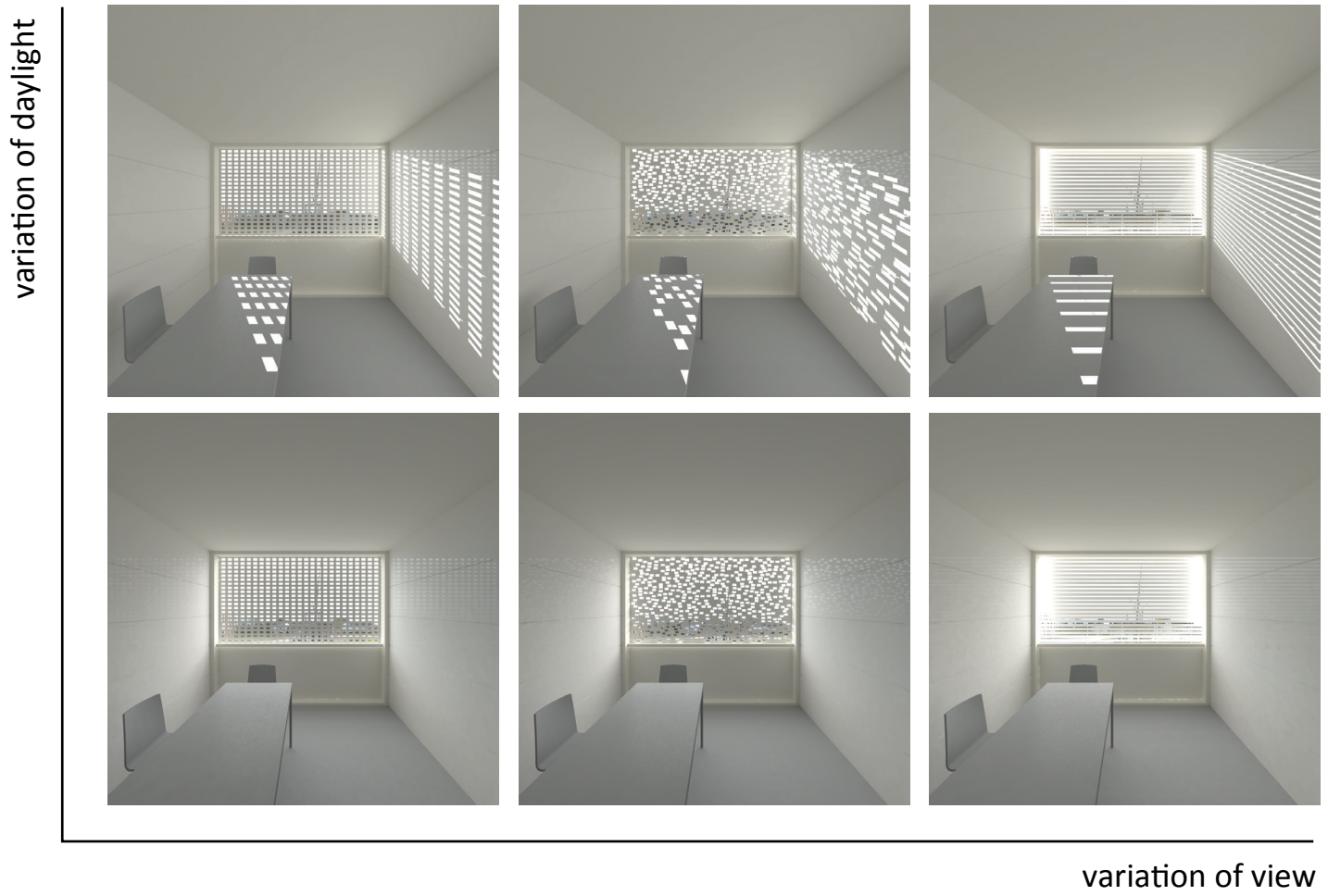
Studied variations of façade patterns



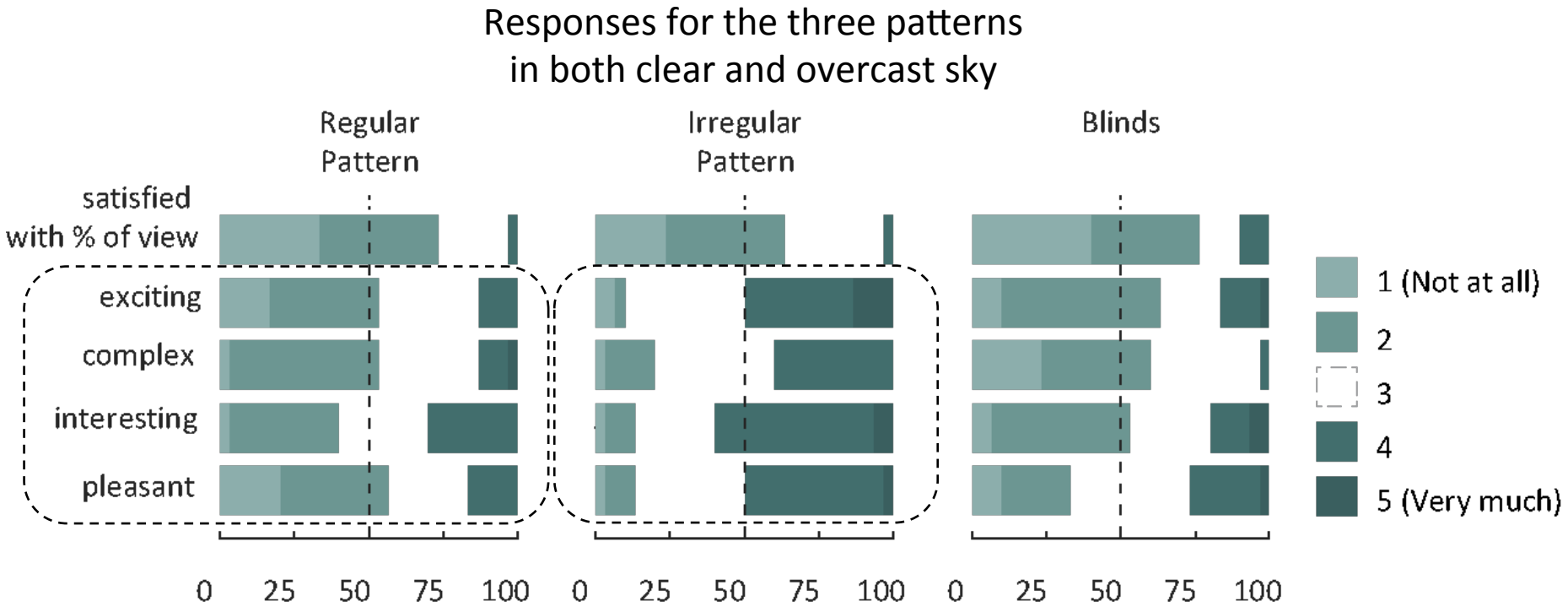
	A	B	C
Opening ratio	✓	✓	✓
Clarity	✓	✓	✓
Geometry of aperture	✓	✓	X
Pattern regularity	✓	X	✓

asibility STudy: FAÇAde PAtterns

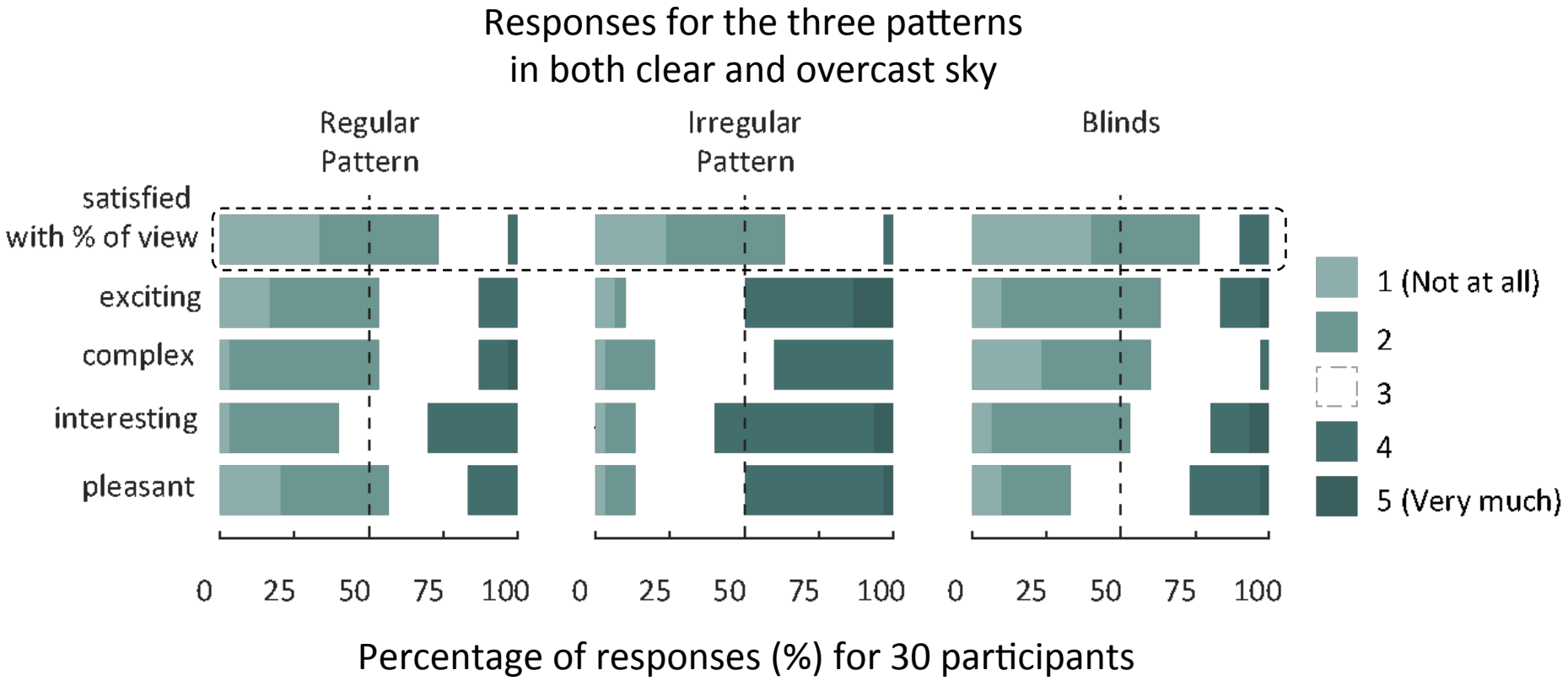
Studied variations of façade patterns



Effect of pattern on the perceived ambience

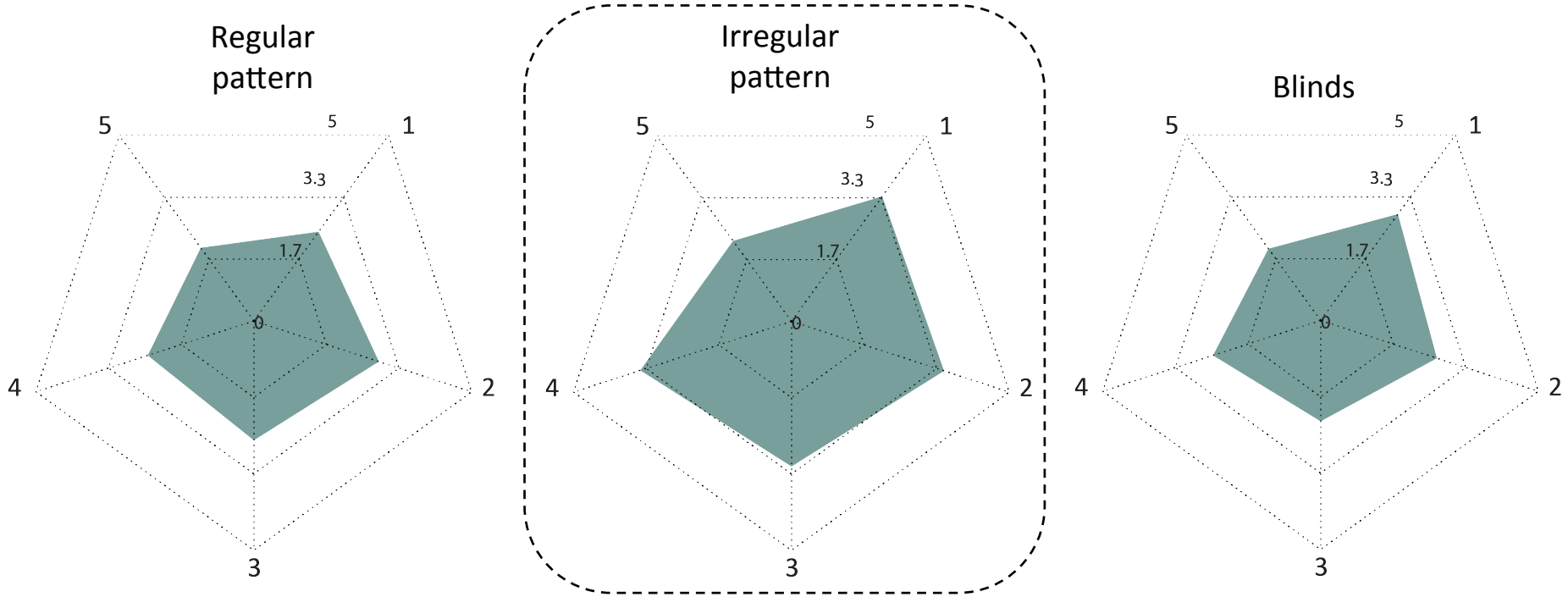


Effect of pattern on the perceived ambience



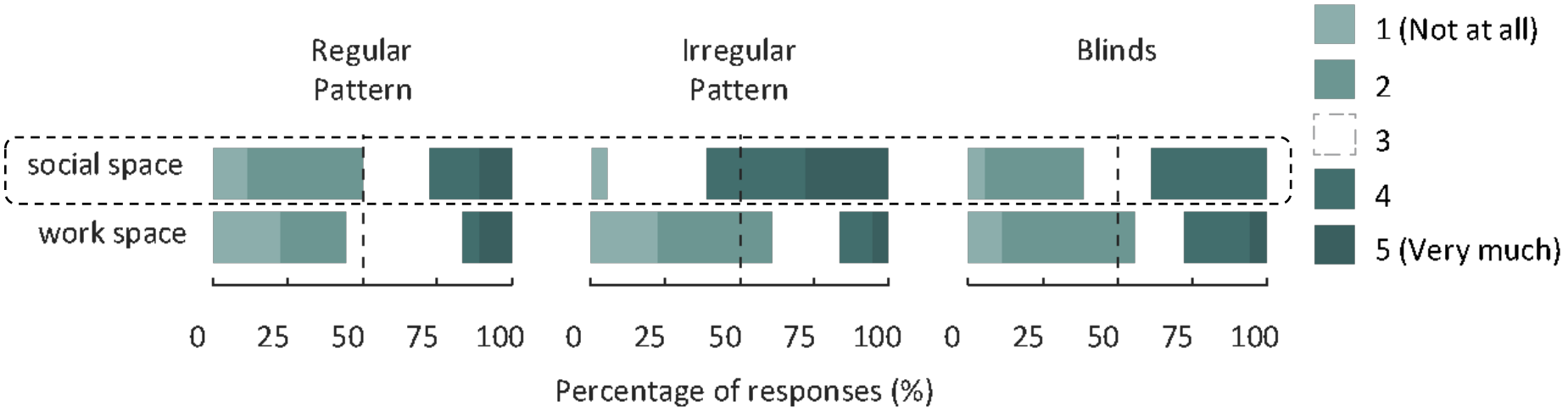
Effect of pattern on the perceived ambience

Mean responses for the three patterns
in both clear and overcast sky



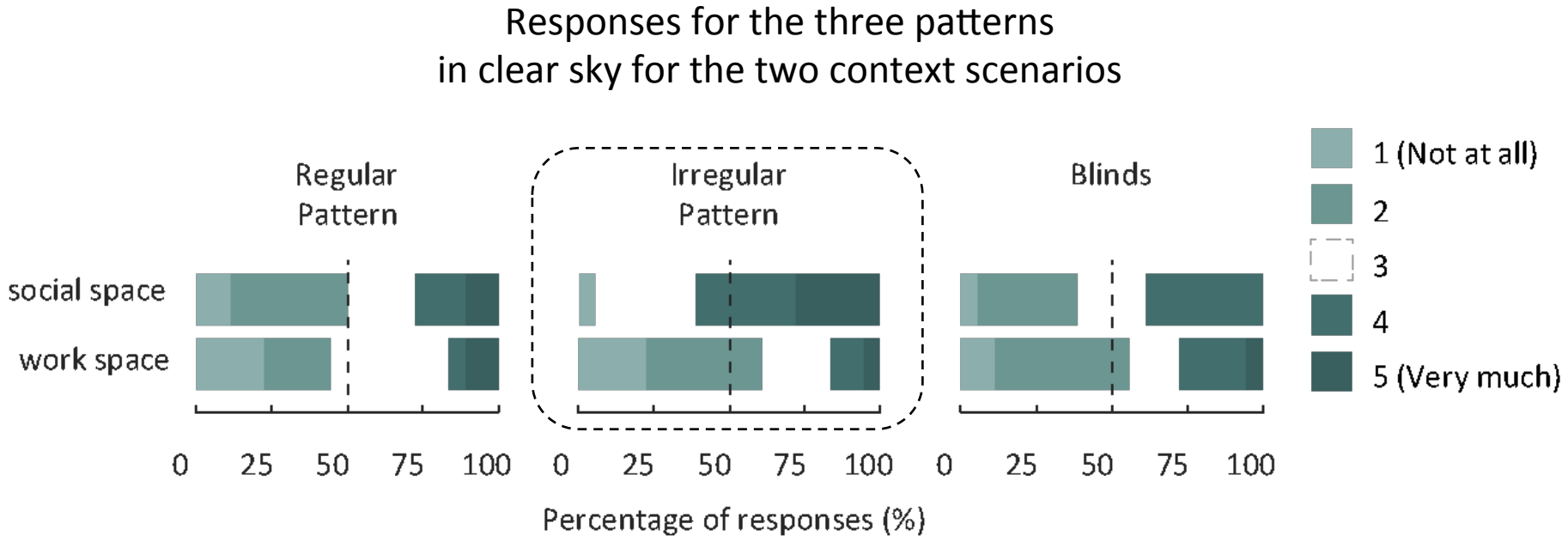
1. pleasant 2. interesting 3. complex 4. exciting 5. satisfied with view

Effect of pattern on the perceived ambience



Percentage of responses (%) for 30 participants

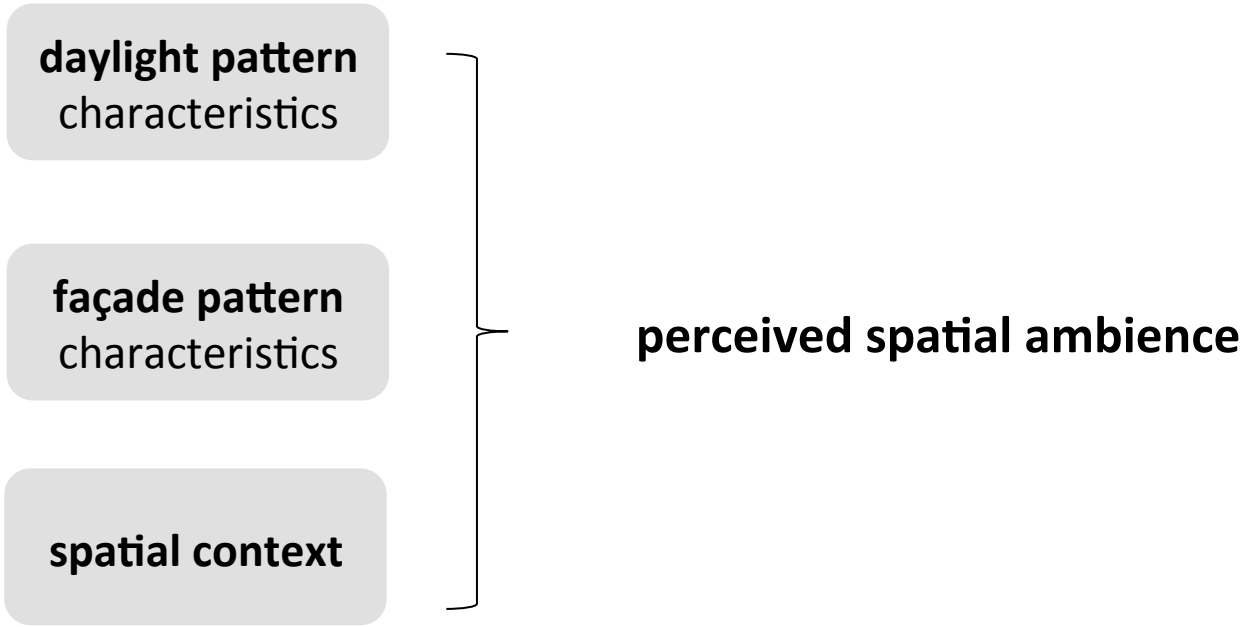
Effect of pattern on the perceived ambience



Percentage of responses (%) for 30 participants

XPERIMENTAL FACTORS

Analysis and Model Development



Analysis and Model Development

daylight pattern characteristics

façade pattern characteristics

local contrast measures
Spatial Contrast[1]*, RAMMG*[2]

spatial context

categorical measure

[Rockcastle and Andersen, 2014[1], Rizzi et al., 2004[2], Mansfield, 2006[3]]

Analysis and Model Development

daylight pattern characteristics

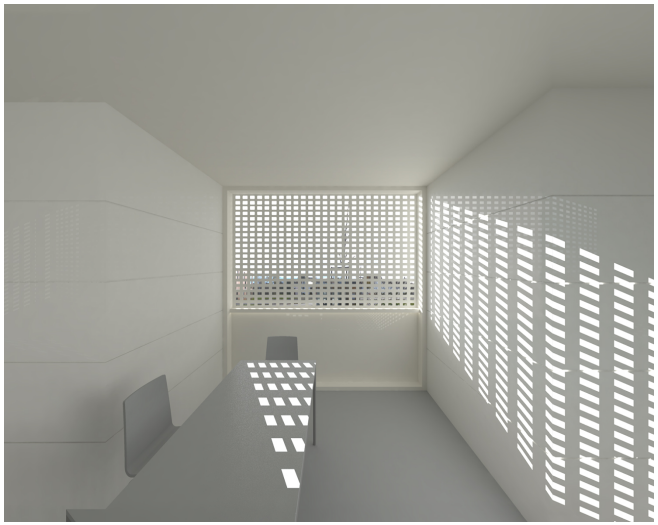
façade pattern characteristics

spatial context

Clear sky

Irregular Pattern

Regular Pattern



Analysis and Model Development

daylight pattern characteristics

façade pattern characteristics

spatial context

Overcast sky

Irregular Pattern

Regular Pattern

Analysis and Model Development

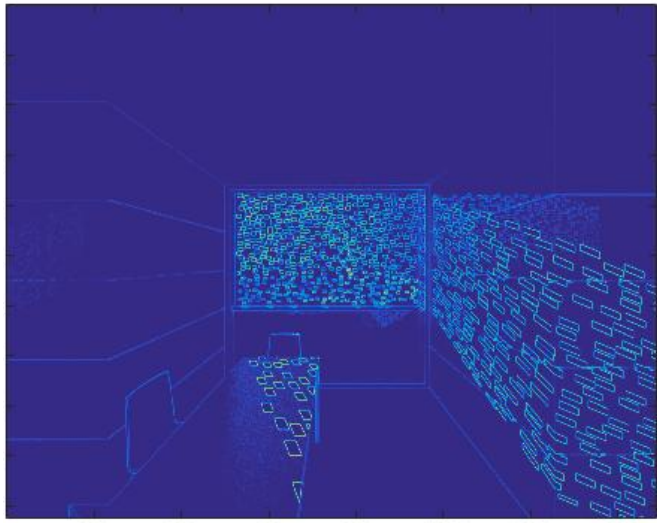
daylight pattern characteristics

façade pattern characteristics

spatial context

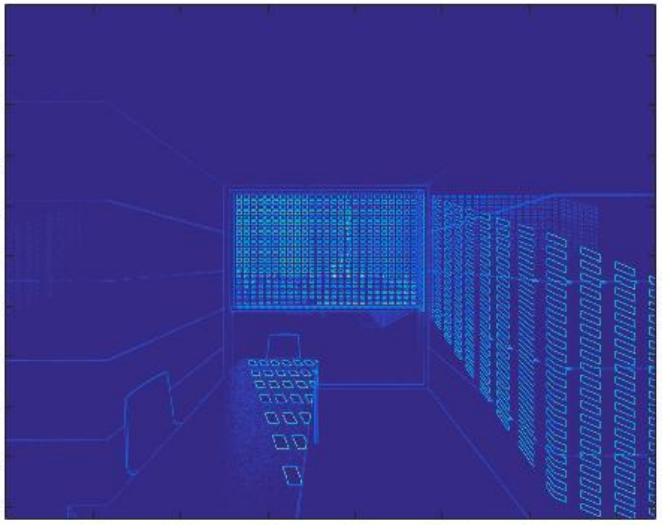
Clear sky

Irregular Pattern



average value: 2.17

Regular Pattern



average value: 2.22

Spatial Contrast[1]

sum of variation in brightness between neighbouring pixels

[Rockcastle and Andersen, 2014[1]]

Analysis and Model Development

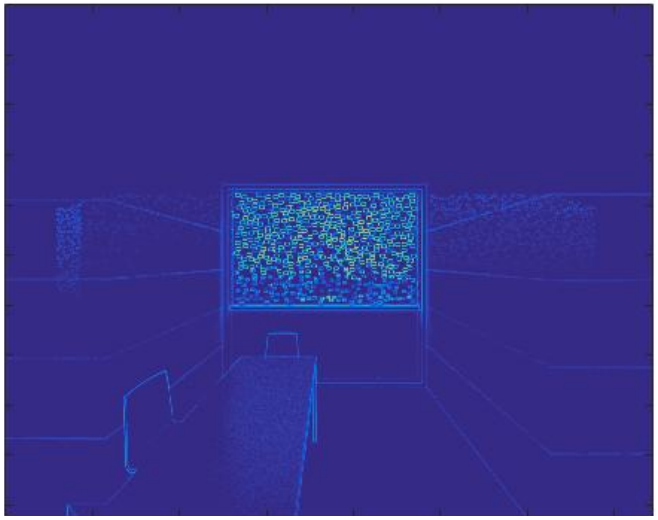
daylight pattern characteristics

façade pattern characteristics

spatial context

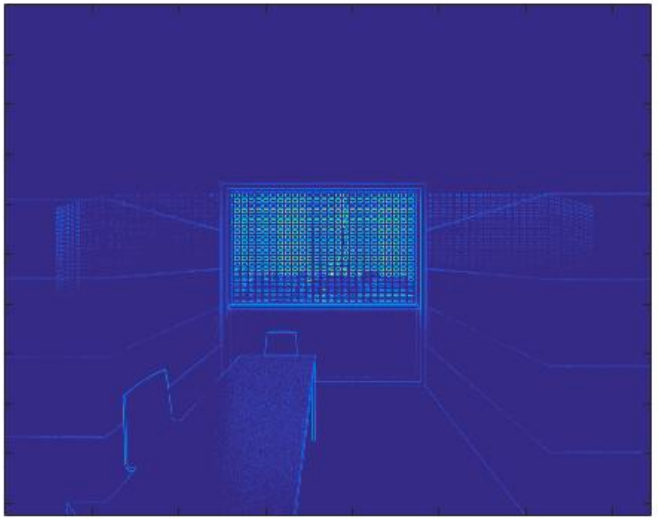
Overcast sky

Irregular Pattern



average value: 1.49

Regular Pattern



average value: 1.55

Spatial Contrast[1]

sum of variation in brightness between neighbouring pixels

[Rockcastle and Andersen, 2014[1]]

Analysis and Model Development

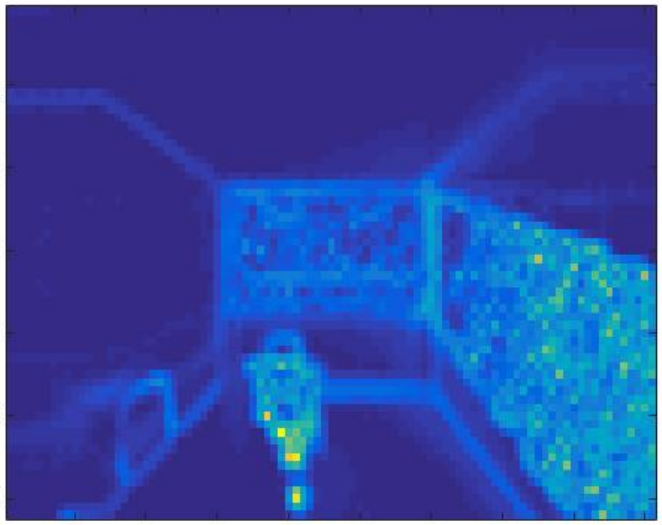
daylight pattern characteristics

façade pattern characteristics

spatial context

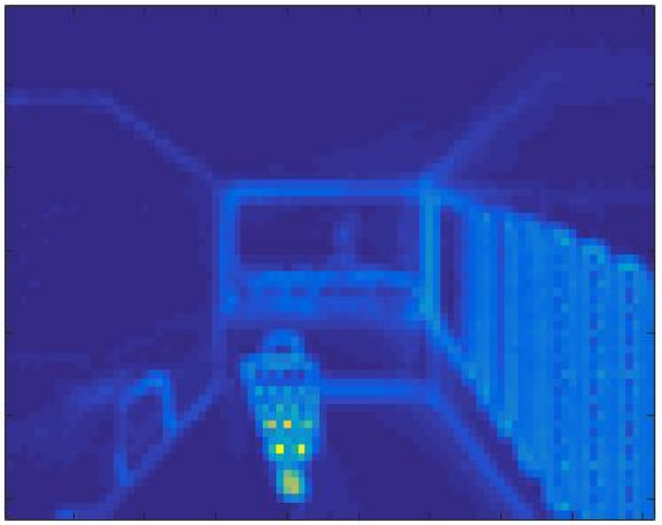
Clear sky

Irregular Pattern



average value: 6.33

Regular Pattern



average value: 5.44

Spatial Contrast[1]

Fifth sampling (RAMM 5 [2])

[Rockcastle and Andersen, 2014[1]]

Analysis and Model Development

daylight pattern characteristics

façade pattern characteristics

spatial context

local contrast measures
Spatial Contrast[1], RAMMG[2]

spatial frequency measures
Fourier Transform[3]

categorical measure

can we **combine** them?

[Rockcastle and Andersen, 2014[1], Rizzi et al., 2004[2], Mansfield, 2006[3]]

ANALYSIS OF RESULTS

ESULTS: EVALUATION OF REAL VERSUS VIRTUAL SPACE


marked attributes:
adequate perceptual accuracy in the virtual space

	N subjects	*Percentage of pairs with absolute difference (%)*				
		0	*1*	*2*	*3*	*0 and 1*
pleasant	28	**50**	32	18	0	**82**
interesting	29	**52**	31	14	3	**83**
complex	29	**76**	24	0	0	**100**
exciting	28	43	47	7	3	**90**
satisfied with amount of view	29	**52**	45	3	0	**97**